The Response to Defects in British Nuclear Submarines

The Scottish Campaign for Nuclear Disarmament

& Faslane Peace Camp

HMS REVENGE returning from her last patrol on 13th April 1992, flying her decommissioning flag and accompanied by a tug with towed array sonar.

Workers from Rolls Royce & Associates carrying out welding and grinding work inside the reactor of HMS REPULSE at Faslane in June 1991.

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INTRODUCTION

There is a serious defect which affects the reactors on nuclear powered submarines in the Royal Navy. The measures which have been taken to adjust to this problem have been inadequate. Polaris submarines have been used on operational patrols when on safety grounds they should have been kept in port.

A substantial weight of evidence has been assembled from a variety of sources. Submarine movements have been monitored and analysed. Individuals with knowledge of these matters have volunteered information. There has been a thorough search through published work covering both the recent situation and the accident record of British nuclear powered submarines.

This report has been compiled by Scottish CND and Faslane Peace Camp. Both groups are committed to creating a country free from nuclear weapons. However, the concerns expressed are shared by a wider cross-section of people, including some of those who have served and are serving on these submarines.

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Scottish CND,
1st June 1992

Abbreviations

DED	Docking and Essential Defects
MoD	Ministry of Defence
MODIX	Reactor pipework decontamination process
PWR	Pressurised Water Reactor
RRA	Rolls Royce and Associates Ltd
SCRAM	rapid insertion of control rods
VSEL	Vickers Shipbuilders & Engineering Ltd

1. BACKGROUND

1.1 NUCLEAR POWERED SUBMARINE ACCIDENTS

The Royal Navy operates a fleet of nuclear powered submarines, including the Resolution class which carry Polaris missiles. The reactors on these submarines are significantly smaller than land based reactors, however they are exposed to greater dangers. Nuclear powered submarines from both the American and former Soviet navies have been lost at sea. Although no Royal Navy nuclear powered submarine has been lost, several have been involved in major accidents [1].

a. Fire

Any fire on a submarine has the potential to become a major incident. Even if it is some distance from the reactor compartment, a fire can have serious implications for the safe operation of the nuclear plant. There have been at least 19 fires on nuclear powered submarines of the Royal Navy between 1963 and 1992 [Annex A.1].

There was a major fire on board HMS WARSPITE on 2nd May 1976 at Liverpool docks. A coupling failed and sprayed oil over the diesel generator room. This room provides power for elements of the adjacent reactor compartment. The fire lasted for five hours and lagging was still smoking many hours later. Five people were taken to hospital and one Marine Engineer Artificer was seriously injured. It was reported that Merseyside Fire Brigade who attended the scene were kept on stand-by for 2 weeks [2]. A generator had to be welded onto the outside of the casing of the submarine. Damage was so extensive that repairs took 105 weeks to complete and cost £8.8m [3].

On 30th April 1992 there was an electrical explosion in the switchroom of HMS TURBULENT which was preparing to leave Devonport. This resulted in a fire in the compartment, next to the reactor. The nuclear plant was working at the time of the explosion but was shut down automatically. The fireman in charge at the scene said that his men were met with a wall of intense heat and that the fire took 3 hours to extinguish. He also reported that the cramped conditions made their task particularly difficult. Due to a failure in the ventillation system fumes spread throughout the boat and 24 casualties suffering from smoke inhalation were taken to hospital [4].

b. Collision

There have been at least 6 collisions involving British nuclear powered submarines between 1963 and 1992 [Annex A.2]. Land based reactors are only exposed to the more remote hazard of an aircraft colliding with the plant.

At Faslane in January 1973 HMS REVENGE, which was being taken out of the dry dock, collided with HMS REPULSE. The hydroplanes on HMS REPULSE were damaged and had to be replaced immediately [5]. HMS REVENGE was probably carrying a full complement of missiles and nuclear warheads at the time.

HMS SCEPTRE collided with a Soviet submarine while both vessels were submerged in the Barents sea in the early 1980s. The propeller of the Soviet submarine scratched the casing of HMS SCEPTRE. In order to regain power, the reactor on the British submarine was given a "battleshort". The automatic shutdown or SCRAM of a submarine reactor can result in the submarine going into an uncontrolled dive [6]. A "battleshort" is a manual override of reactor safety systems.

c. Fishing boats

The MoD has detailed 12 incidents between 1980 and 1990 involving Royal Navy submarines and fishing vessels [Annex A.3]. There have been others before and since. The sinking of the ANTARES by HMS TRENCHANT on 22nd November 1990 showed that the Captain of a submerged submarine may not have a clear picture of the position of vessels on the surface [7]. Operational Polaris submarines do not use active sonar for fear of revealing their position. Passive sonar is used but the information which it provides is less precise.

d. Grounding

There have been a number of occasions when submarines have been grounded [Annex A.4]. It is believed that a grounding incident in 1986 led to the premature decommissioning of the USS Nathanael Green [8]. It is likely that the shock of a grounding incident would lead to a reactor shut down. Water for the Emergency Cooling System may only be available from ballast tanks if the vessel is grounded.

e. Breakdown at sea

Mechanical breakdowns at sea are quite common and can present a hazard. Five such occasions have been noted [Annex A.5]. One of the most dramatic involved HMS REVENGE. There was a major steam leak in the turbo generator room. One member of the crew crawled along a foot wide catwalk beneath a hot cloud of escaping high pressure steam searching for the leak. It was said that his action prevented a major disaster. In May 1978 he was one of two submariners presented with awards for gallantry relating to this incident [9].

f. Loss of power

There are automatic systems which shut down the reactor to prevent a melt down. Emergency shut downs or SCRAMs occurred on 106 occasions on Royal Navy submarines between 1975 and 1979. This included 50 accidental SCRAMs, 29 of which were due to human error [10]. A sudden loss of power can threaten the safety of the submarine [11].

1.2 EARLIER PROBLEMS WITH PWR 1

a. Background

British research into Pressurised Water Reactors [PWR] began at Harwell in 1954. Rolls Royce and Associates [RRA] was formed in 1959 to facilitate the transfer of technology from

the United States to Britain [12]. The Dounreay Submarine Prototype Reactor was established at HMS Vulcan in 1962. This incorporated features of both British PWR development and the American Westinghouse S5W design.

The first United States Navy submarine to be powered with this Westinghouse reactor was commissioned in 1959. The Royal Navy was supplied with a similar reactor for HMS DREADNOUGHT, which was commissioned four years later. Under the sales agreement the United States undertook to provide information relating to problems encountered with the reactor on HMS DREADNOUGHT during its lifetime. However, having supplied the initial reactor and design details, the United States was not willing to supply information about modifications [14]. There has not been a continuous sharing of expertise. RRA has relied on its own experience based on the performance of the unique prototype at Dounreay and the reactors in service on Royal Navy submarines.

b. Refits and DEDs

Major work on the reactor of a nuclear powered submarine is carried out during refits. The reactor is refuelled and essential repairs are carried out. 1/5 of the 1000 butt welds in the reactor compartment may require cutting and rewelding [15].

18 months before a refit inspections are carried out on the submarine to assess what work will be required [16]. It might be expected that reactor defects would be detected at this stage or when the vessel arrives at the dockyard. However it is apparent that on several occasions significant reactor defects have only been discovered during the closing stages of a refit. Problems were detected during final power testing on HMS RESOLUTION in 1976, on HMS RENOWN at the end of a refit in 1980, during a Docking and Essential Defects [DED] on HMS WARSPITE in 1984 and at the end of a refit on HMS VALIANT in 1988 [Annex B.1].

RRA has facilities to develop and practice repair techniques at Dounreay and elsewhere [17]. Nevertheless there have been cases where serious reactor problems have been detected for which no tried and tested repair methods were available. There are references to "innovative engineering" on HMS WARSPITE during a DED in 1984, a "major innovative repair" on HMS REPULSE in 1986 and "novel tasks" carried out on the reactor of HMS VALIANT in 1988 [Annex B.1].

c. Problems encountered while in service

HMS VALIANT was at sea off the coast of Cornwall in May 1981 when there were difficulties with the reactor. On returning to Devonport it was discovered that there were small cracks in part of the Primary Coolant Circuit. 6 months earlier the reactor on board HMS DREADNOUGHT was shut down because of major machinery damage. HMS DREADNOUGHT was subsequently decommissioned. Problems on the two vessels may have been related [Annex B.2].

There were problems with the materials used in the seals of valves. Corrosion of seals could have led to a major and catastrophic loss of coolant. No assistance was provided from the United States Navy which had been aware of the problem [18].

1.3 PROBLEMS ON AGEING SUBMARINES

a. Design life

It is clear that the original design life of Resolution class submarines was 20 years [19]. With regard to Vanguard class submarines the plant life for PWR 2 is the same as the planned submarine life [20]. It is reasonable to assume that in the 1960s the MoD asked RRA to supply a reactor system which would operate safely for 20 years. This design life expired in the Valiant class in 1987, Resolution class in 1989 and Churchill class in 1992.

b. Problems encountered

Systems on board the submarine were designed with this lifespan in mind. In addition to reactor fractures it is apparent that there have been a series of defects affecting ageing nuclear powered submarines. These problems are liable to multiply the longer a vessel is in service and could affect the safety of reactor operations.

As a submarine becomes older, restrictions are placed on how deep the vessel can dive. It is believed that Resolution class submarines have had difficulty in passing diving trials.

There were noise problems on HMS RESOLUTION which resulted in a visit to Rosyth in 1986/87 for special repairs. Regular visits to Loch Goil indicate that there may also have been noise problems with HMS REVENGE from 1990 to 1992.

HMS REPULSE was engaged in a month of trials operating from Coulport in Spring 1992 suggesting that there may have been problems with the vessel.

2. REACTOR DEFECT FOUND IN 1989

2.1 SUBMARINES AFFECTED

a. Valiant class

In December 1989 a major defect was discovered in the reactor on HMS WARSPITE during a refit at Devonport [1]. There has been conflicting information on whether or not a cost effective repair was possible [2]. In September 1990 it was announced that the vessel would be decommissioned.

HMS VALIANT was berthed at Faslane from January 1990 to June 1991. The submarine was then in use for less than a year. In April 1992 there was a formal farewell for the vessel before she sailed to Rosyth [3]. It is likely that the submarine is due to be decommissioned.

b. Resolution class

HMS RENOWN arrived at Rosyth for her third refit in October 1987 [4]. By early 1990 the submarine had been taken out of the refuelling dock and was almost ready to leave. It was then decided to carry out extra work on the reactor. Either fractures were found or it was decided that major preventative action was required to ensure they would not appear [5]. This work has taken more than 2 years. As well as the fracture problem there have been a series of other defects. The total time required for the refit has been revised from two years to five years [6].

On 9th December 1991 it was announced that HMS REVENGE would not be given the third refit scheduled but would be scrapped [7]. There had been indications earlier in the year that this would happen.

It is reasonable to assume that the probability of the defect occurring will increase with the number of years the reactor has been in operation. The length of service of individual submarines can be estimated by deducting time spent in refits from the total time since a vessel was first commissioned [Annex D.2]. This calculation shows service life as: HMS RENOWN 15 years 11 months, HMS REVENGE 18 years 5 months, HMS REPULSE 18 years 8 months, and HMS RESOLUTION 20 years. There was serious concern about HMS RENOWN which has spent the shortest time in service and so there ought to be even greater concern about the other three Polaris boats.

c. Churchill Class

The defect found on HMS WARSPITE was also found on HMS CHURCHILL. HMS CHURCHILL was in refit at Rosyth where she remains. In September 1990 it was announced that the boat would be decommissioned. The problem with the boat was only revealed in June 1991, by the House of Commons Defence Committee [8].

The decommissioning of HMS CONQUEROR was announced in July 1990 and the submarine was towed out of Faslane on 30 August 1990 [9]. While there has been no indication of the problem with HMS CONQUEROR it is clear that a serious fault was discovered shortly after the defect was found on HMS WARSPITE.

HMS COURAGEOUS was berthed at Faslane from January 1990 until July 1991. The boat was then in use for less than one year. In April 1992 she was flying a decommissioning flag immediately before sailing to Devonport Dockyard [10].

There are now no Valiant or Churchill class submarines in service. While this was explained as due to defence cuts, the material state of the vessels was a major factor [11]

d. Swiftsure Class

HMS SWIFTSURE is currently in Rosyth dockyard. While it is possible that a refit may be taking place, the concensus of opinion is that the boat will be decommissioned.

HMS SPARTAN, HMS SCEPTRE and HMS SUPERB have all been berthed at Faslane for long periods of time during 1991 and 1992 [12]. This may have been to enable detailed inspections to take place.

e. Trafalgar class

When the defect was first noticed in January 1990, Trafalgar class submarines were being used to carry out tasks previously assigned to other vessels. There have been no obvious signs that these newest submarines are affected. However the MoD has said that when the defect was found on HMS WARSPITE an inspection process was begun affecting all nuclear powered submarines [13].

f. Vanguard class

The new Vanguard class submarines which will carry Trident missiles have a completely new reactor, the PWR 2. However when questioned about the possibility of the defect having implications for Vanguard class, the MoD have not given the categorical denial of any risk which might have been expected [14].

g. Submarines most at risk

There is some concern about the nuclear reactors on all nuclear powered submarines, which has necessitated a comprehensive inspection programme. However there are indications that the ten oldest submarines were most at risk.

It has been said that a substantial change in design was made after the first ten PWR reactors were built [15]. RRA carried out research into a problem affecting ten boats [para 2.2]. Of these ten submarines eight are not currently in service: HMS VALIANT, WARSPITE, RENOWN, REVENGE, CHURCHILL, CONQUEROR, COURAGEOUS and SWIFTSURE. Only HMS REPULSE and RESOLUTION are currently in use [Annex C].

2.2 NATURE OF REACTOR DEFECT

It is apparent that fractures were discovered in the Primary Cooling circuit of the PWR 1 reactors. The weak points in the circuit are welds joining two different alloys. There are a number of factors which can weaken the welds. Firstly, radiation has a detremental effect. Secondly, fluctuations in temperature can make the metal more brittle. Thirdly, poor water chemistry in the coolant circuit can contribute to corrosion [16].

In Spring 1991 a worker at VSEL in Barrow was commended for a project completed for RRA. A large volume of welding was carried out in order to replicate techniques which had been used in the 1950s and 1960s. A weld was made between two different types of steel. The 500kg test piece had to be continuously heated to 150 C. A photograph shows that it could be a junction on the Primary Circuit of the PWR 1

failure. As a result of the loss of coolant water the fuel cladding could eventually melt, releasing radioactive fission products into the compartment containing the reactor ..... If, following these events, the submarine's primary containment were itself to fail to some degree fission products would become dispersed throughout the submarine" [22].

There is also a possibility of more extensive damage. During the initial rupture there would be a steam explosion. If this was very severe it could result in damage to the Reactor Pressure Vessel and a major disaster [23].

A major rupture of the Primary Circuit would endanger the lives of those on board the vessel, particularly if the accident took place at sea. If the accident could not be effectively contained there would be a significant radiation risk to the general public. The problem could be complicated by a failure in the Emergency Cooling System.

RRA have conducted experiments into Loss of Coolant Accidents using the decontaminated Dounreay Submarine Prototype, with an electrical heater replacing the reactor core [24]. It can be assumed that these have been used to support safety cases made between 1990 and 1992.

3. INSPECTION AND REPAIR PROGRAMME

3.1 DEVELOPMENT OF TECHNIQUES

On 18 January 1990 HMS RESOLUTION returned to Faslane after 4 days of a 10 day exercise [1]. By the end of January all Valiant, Churchill and Resolution class submarines were either berthed or in refit, except for one Resolution class on patrol. The MoD said that submarines would be inspected when they returned from patrol [2]. HMS WARSPITE was used as a test bed for inspection techniques. A two stage inspection process was implemented. By November 1990 the second stage had not been carried out on HMS VALIANT, HMS COURAGEOUS, HMS SWIFTSURE or HMS SOVEREIGN [3].

Inspection involved highly complex work and there have been problems with access to the affected area [4]. This has contributed to the time taken [5].

The ability to carry out a complex task on a PWR 1 reactor is restricted by the level of radioactivity in the compartment. This can be reduced by decontamination processes. A major source of radioactivity is the build up of crud on the inside of the Primary Circuit which increases with the service life of the reactor [6]. In April 1980 HMS REVENGE began a refit at Rosyth. Levels of radiation were such that it was calculated that the refit could take 3 years [7]. As an alternative it was decided to decontaminate the Primary Circuit pipework. This process produced 7.3 curies of radioactive waste [8]. The original process was replaced by a new process in 1985 which was used at the first stage of refits from 1986 onwards [9].

Detailed inspection would be most easily carried out on reactors which were undergoing refit and which had been decontaminated. This would apply to HMS WARSPITE, HMS CHURCHILL and HMS RENOWN. It would appear that the fault was found on at least two and possibly all three.

The ability to carry out a detailed inspection, other than after decontamination, should be questioned. The MODIX process has only been used at dockyards and takes 3 months [10]. There is no evidence to suggest that reactors at Naval Bases have been decontaminated to facilitate inspection work.

The use of remote technology to conduct work in PWR 1 reactors has in the past been problematic [11]. The compartment is cramped and initial attempts to use remote machinery during refits were not successful. On at least one occasion a job which should have been done by machine was done by hand [12].

The inspection techniques may not be able to adequately judge the seriousness of the problem. Restrictions were placed on visits to foreign ports because of a concern that problems with cracks might be worse than assumed [13].

In order to provide adequate safety, inspection techniques would have to prove a high level of success in detecting fractures at an early stage and before they constituted a serious safety hazard. The length and nature of planned reactor operations following the inspection would have to be taken into account.

3.2 CONDUCT OF INSPECTIONS

It is apparent that thorough inspection techniques were not available during the first half of 1990. Despite this, all three available Resolution class submarines were sent on patrol [Annex E].

It would appear that in the case of HMS REPULSE a routine inspection did not detect any problems and the submarine was sent out on patrol. After the vessel returned to Faslane in July 1990 a fault in the reactor was discovered. It is not unreasonable to assume that the defect was present before and during the patrol.

Between July 1990 and July 1991 HMS RESOLUTION was used so extensively for patrolling that the longest period spent at Faslane was only 54 days. As the reactor had to be allowed to "cool down" it is unlikely that this was long enough to carry out a thorough inspection. It would appear that HMS RESOLUTION was sent out on two very long patrols without a detailed inspection of the reactor having been completed. In addition, after returning from a 108 day patrol in June 1991 the submarine spent only 7 days at Faslane before being sent out for a further 30 days on patrol. After this HMS RESOLUTION spent 5 months at Faslane during which time a number of containers belonging to RRA were seen alongside. This suggests that a detailed inspection was carried out in the Autumn of 1991.

The exposure of workers during inspections will vary with each reactor. The level of radioactivity increases with the service life of the reactor. While there is no public information about this, it is known that HMS REVENGE came out of refit in January 1983, HMS RESOLUTION came out of refit in September 1984, and HMS REPULSE came out of refit in October 1986 [Annex C.1]. It could be assumed that it would be most difficult to carry out an inspection of HMS REVENGE.

3.3 REPAIRS

It is likely that a range of repairs have been attempted. An effective repair may have been carried out on HMS RENOWN at Rosyth by fixing trouser leg seals [14]. It has taken over 2 years to complete this work. This reactor would have been relatively easy to work on as pipework had been decontaminated in 1987 and the vessel was in a dry dock at Rosyth dockyard.

It is unlikely that other repairs have been as effective. Some form of repair was carried out on the Steam Generator of HMS VALIANT in a 6 month period at Rosyth in 1988. Some form of repair has been made to HMS REPULSE over a 13 month period at Faslane. Further work was carried out one month after the vessel returned from patrol [15].

There were reports that a pipe was ground down on HMS REVENGE following the discovery of a reactor problem in February 1990 [16]. A proper repair of the defect had not been developped at this time and would have taken longer to complete.

In 1991 two different treatments of the defect were being considered and the experts were not certain which would be the most effective [17].

3.4 HAZARDS POSED TO WORKERS

There is a marked increase in the levels of radiation to which workers were exposed at Faslane in 1990 in comparison with previous years [18]. This would appear to be in connection with inspection and repair work carried out to keep vessels at sea. There are reports that workers sent from Rosyth to Faslane were exposed to high levels of radiation in order to complete work on reactors on time during 1991 [19]. There may have been a conflict between pressures to keep one Polaris boat at sea and maintaining low levels of exposure to workers.

4. USE OF SUBMARINES AT MOST RISK

4.1 USE OF HMS VALIANT AND HMS COURAGEOUS

HMS VALIANT and HMS COURAGEOUS continued in service from 1990 until 1992. Both vessels were berthed at Faslane from the beginning of 1990 for 17 months. The crews were reduced as if the vessels were in refit [1]. In April 1991 the future of both submarines was uncertain. It was suggested that they might be retained in order to provide training opportunities for submariners [2]. Containers belonging to RRA were alongside these vessels during 1991, probably carrying out inspections. HMS VALIANT went out to sea in June 1991 and

HMS COURAGEOUS in July 1991. They later put to sea on several occasions, possibly to provide training for submariners. They were not used for any long patrols. In April 1992 both vessels were sailed into dockyards, probably for decommissioning.

Restrictions were placed on visits to foreign ports by nuclear powered submarines, because of concern that a nuclear accident might occur [3]. Resolution class boats do not make such visits, except to the United States.

4.2 USE OF RESOLUTION CLASS

a. Work Up Exercises

The normal routine before the start of an operational patrol is that the submarine carries out a 10 day work up exercise [4]. This is required both to ensure that the equipment on the vessel is functioning correctly and to exercise personnel in their individual tasks and as a crew. There is a short period between the end of the exercise and the departure on patrol which is used to work on any problems encountered at sea.

Between July 1990 and January 1992 the only exercise carried out by HMS REVENGE was for 4 days in November 1990. No exercises were carried out before patrols in May and July 1991. No exercise was carried out before the patrols by HMS RESOLUTION in June and December 1991 [Annex E].

The length of tne exercise period required for both the vessel and crew are longer if a submarine has not been in service for some time [5]. HMS REPULSE was berthed at Faslane for 13 months. A long trials period would have been expected to follow this. The 23 day exercise period was shorter than might be expected.

b. Change Over

It takes approximately 7 days for a submarine to reach its patrol area. The submarine going out should reach its patrol area before the submarine being relieved returns to base. Between July 1990 and January 1992, change over periods were 4 or 5 days and in one case 12 hours [Annex E].

c. Length of Patrols

Prior to 1989 patrols were of a regular length of around 8 weeks [6]. During 1990 and 1991 patrols varied in length between 16 days and 109 days [Annex E]. The long patrols were only 4 days shorter than the longest patrol ever completed by a Royal Navy nuclear powered submarine [7].

d. Proportion of boats at sea.

In the past there were said to be an average of 1.44 Polaris boats at sea [8]. From January to December 1991 there were an average of 1.16 Polaris boats at sea Annex E].

4.3 COMPARISON OF USE OF RESOLUTION AND OTHER CLASSES

Changes to operational practice suggest that the MoD is conscious that each of the Resolution class boats could be affected by the defect. There has been a deliberate policy of restricting the operation of Resolution class submarines to the minimum required to maintain one boat at sea at all times. This has still required extensive use of all three boats and is in contrast with the greater degree of caution exercised in the operation of HMS VALIANT and HMS COURAGEOUS. The hunter killer submarines have only been used in a limited role, after inspection techniques were developed.

5. EXTENDED COMMISSION LENGTH

5.1 HMS REVENGE

Prior to 1990 the longest period of service completed by a Resolution class submarine between refits was of 7 years and 5 months completed by HMS RENOWN between 1980 and 1987 [1]. In 1977 a new type of reactor core was installed in the Dounreay Submarine Prototype. This core was fully burned up by 1985 after having been in operation for less than 8 years [2].

HMS REVENGE completed her second refit in January 1983 and it is reasonable to assume that it was planned that the third refit would be underway by Spring 1990 [3]. This would have meant 7 years service between refits.

The refit of HMS RENOWN was extended by three years and HMS REPULSE was out of action for much of 1990 and 1991. As a result HMS REVENGE was kept in use for longer than originally planned. HMS REVENGE completed her final patrol 9 years and 6 month after the submarine came out of refit. While actual reactor service life is not the same as years of service this is the best guide publicly available.

It would appear that extended service did have an effect on the reactor. It has been said that the third refit of HMS REVENGE would have taken 3 years, instead of the normal 2 years [4]. There have been reports of problems in operating the Control Rod Drive Mechanisms on the reactor. There have also been reports of regular losses of power.

There is reason to believe that serious problems were encountered at sea on board HMS REVENGE during an 11 week patrol between December 1990 and February 1991. During this time there were recurring problems with the reactor on HMS REVENGE, which may have lost power on 24 occasions. Safety mechanisms were overridden to regain power.

The fuel rods were in use beyond the end of their intended life. When the reactor was running there would be a build up of fission products which would cause a shut down. This may have happened so frequently on HMS REVENGE that reactor power was only available for less than 7 days at a time. The operators should have been able to predict each loss of power. It would then take several tense hours to restart the reactor because of the effects of "xenon poisoning" [5].

A large amount of power is required to start the reactor and battery supplies are limited. These can only be recharged by diesel when the vessel is close to the surface. It is possible that circumstances arose in which safety mechanisms were overridden to regain power. It is possible for a shut down of the reactor to lead to an uncontrolled deep dive of a submerged submarine [6].

When HMS REVENGE was due to go to sea again at the end of May 1991, it would appear that she was not fit to complete a long patrol. She was sent out to sea for 17 days during which time HMS RESOLUTION was resupplied, changed crews and returned to sea [Annex E].

Reactor problems are likely to have recurred during the last long patrol from June to September 1991. When the submarine returned to Faslane on 23rd September 1991 there was a request that the Mechanical Engineering Officer from the alternate crew be alongside when the vessel arrived. This officer is responsible for reactor operations. Immediately after the submarine berthed a number of reactor personnel went down into the reactor area.

Because of unidentified problems with HMS REPULSE, HMS REVENGE was sent out on a final short patrol in March 1992. All missiles were offloaded from the vessel in April 1992.

5.2 RESOLUTION CLASS 1992 - 1997

a. Nine year commissions

Forward planning of the deployment of Resolution class submarines of the Polaris force is not public knowledge. Nevertheless it is possible to project what this is likely to be on the basis of earlier information. It would appear that the planned life of Polaris submarines between refits in the late 1980s and 1990s was 7 years. On this basis HMS RESOLUTION should have been decommissioned in late 1991 or early 1992. However the schedule has been upset by the extended refit on HMS RENOWN. It is likely that the Royal Navy is planning to continue running HMS RESOLUTION and HMS REPULSE for 9 years [Annex F]. This could result in a whole series of problems on these vessels, including the difficulties which were experienced on HMS REVENGE.

b. Two/three boat availability

Polaris submarines have in the past only become operational after completing a 9 month post-refit trials period which culminates in missile tests in Florida. Refits at Rosyth are "back to back" [Annex D]. This means that there have been periods of around 9 months when one submarine is on trials, one is in refit and only two are available for operations. The Royal Navy are not confident that a continuous patrol can be maintained with only two boats for longer than 9 months [7].

There were only two boats in use from July 1990 to July 1991 when HMS REPULSE was out of action. With the decommissioning of HMS REVENGE in April 1992 there are again only two boats available. This will remain the case until post refit trials are completed on HMS RENOWN, which may not be until Summer 1993 [8]. If it is planned to try to keep three boats available from 1993 onwards, this can only be achieved by further extending the use of HMS RESOLUTION and HMS REPULSE.

6. EMERGENCY COOLING SYSTEM

6.1 CONCERN ABOUT EMERGENCY COOLING SYSTEM

Anonymous information obtained by Scottish CND on two occasions suggests that while there are fractures in the primary circuit these are only part of the problem. The real danger is that in the event of these fractures causing a loss of coolant accident, the safety mechanisms would not operate as intended. On one occasion it was said that the Emergency Cooling System does not work. On a second occasion it was said that the main danger is final coolant failure, which could refer to failures in the Emergency Cooling System [Annex G].

Any doubts about the reliability or effectiveness of the Emergency Cooling System is cause for serious concern. The proper functioning of this system is essential for safe operation of nuclear reactors on submarines. Any doubts over the effectiveness of this system would bear heavily on safety calculations made over the operation of submarines which may be subject to fractures in the primary circuit and to the operation of reactor cores beyond their planned service life.

6.2 INCIDENT ON HMS RESOLUTION 26 January 1988

In the information refered to above there were references to an incident which could have resulted in a melt down. It is almost certain that this refers to an incident on HMS RESOLUTION on 26 January 1988.

HMS RESOLUTION had completed a work up exercise and was berthed at Faslane making last minute preparations before going out on patrol. The reactor would have been at high pressure and may have been in the process of being brought up to power. It was reported that the electricity supply to the reactor coolant pumps was shut off, two back up pumps failed as did a further emergency power supply. Two crewmen raced to start up a diesel generator [1].

It is likely that there have been a number of similar occasions when there has been a loss of power, and/or failure of coolant pumps on board nuclear powered submarines. Although not unique the incident was serious. The MoD was misleading the public in describing this as a "minor electrical malfunction" [2]. Any sudden loss of coolant flow in the primary coolant circuit a PWR nuclear reactor is a serious incident.

7. CONCLUSION

There have been at least 45 serious incidents involving Royal Navy nuclear powered submarines, including fires, collisions and encounters with fishing boats. A submarine is not a safe place to put a nuclear reactor.

Submarines of the Valiant, Resolution and Churchill classes have all now past the end of the life for which they were designed. Those vessels which have been kept in service have experienced a series of problems.

There have been unofficial reports that fractures have been found in welds in the primary coolant circuit of PWR 1 nuclear reactors. It is reasonable to assume that this is the defect which led to HMS WARSPITE and HMS CHURCHILL being decommissioned. Four other submarines with similar reactors have also been withdrawn from service. It is clear that all Polaris submarines are affected by this defect.

On several occasions in the past reactor problems have only been identified at one of the nuclear submarine dockyards where such faults are rectified. Work at Rosyth to tackle the primary coolant circuit defect on HMS RENOWN has taken 2 years to complete. Inspection and repair work which has been attempted on other vessels at Faslane will not have been effective. It will have been hampered by radiation levels in reactor compartments.

The nature of the fault may be such that detailed inspections will not detect the fractures in time. Inspections in themselves are unlikely to be sufficient.

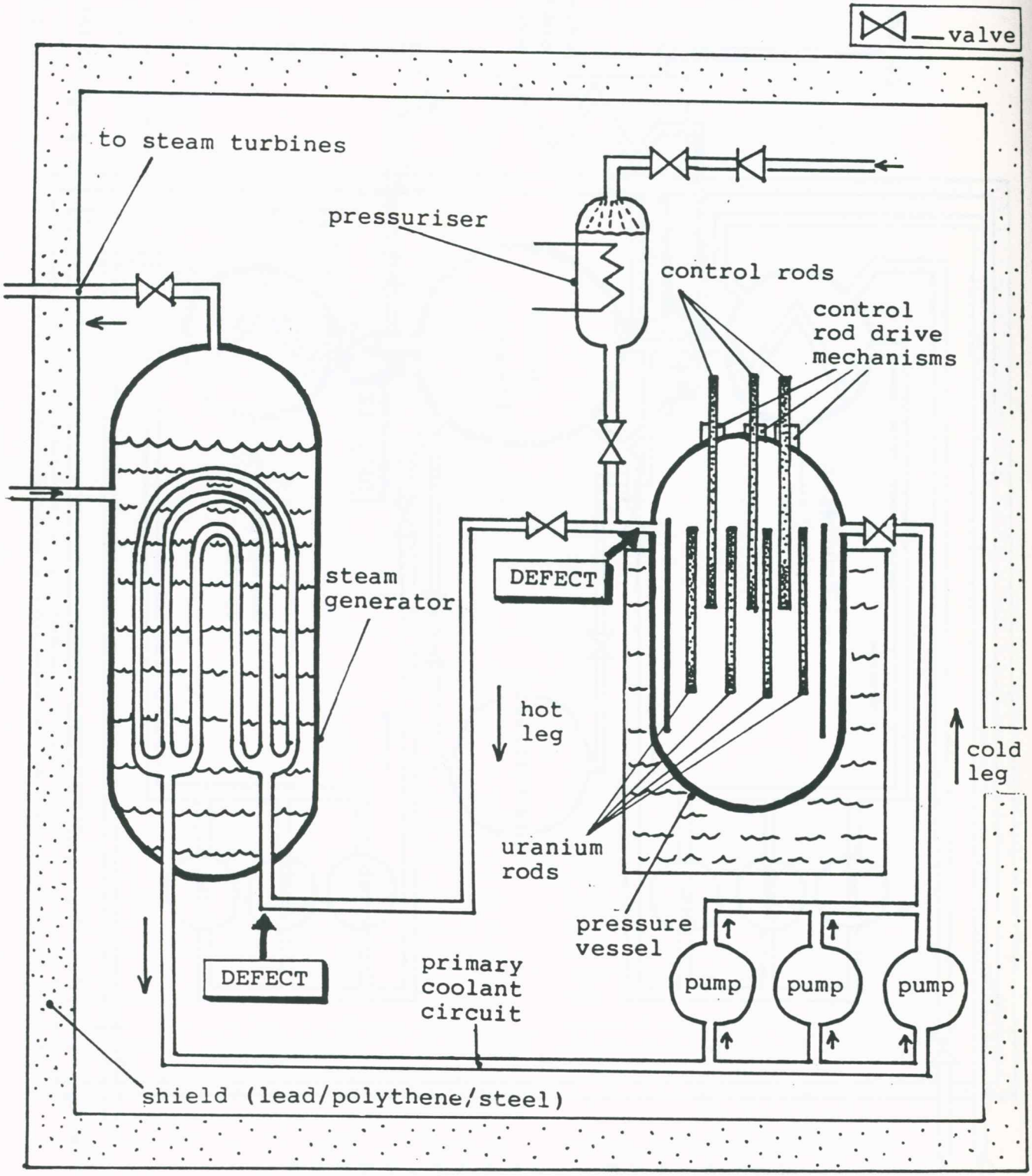
Fractures in the Primary Coolant Circuit could lead to a major Loss of Coolant Accident and casualties amongst the submarine crew. There is the chance of an even more serious nuclear disaster. The consequences would be worse if, as has been suggested, the Emergency Cooling System is unreliable.

While there is concern about all Royal Navy nuclear powered submarines, the older vessels are particularly at risk. The implications of the defect have placed severe constraints on the operation of Valiant and Churchill class boats. All vessels of these classes have now been withdrawn from service.

Polaris submarines have been equally at risk from the same defect but have been used very extensively. Normal routines have been abandoned in order to maintain one Polaris submarine at sea at all times. HMS RESOLUTION spent 20 weeks at sea in a 21 week period in 1991. There were serious problems in maintaining power on board HMS REVENGE when the submarine was kept in service for nine years instead of seven. The MoD can only continue to maintain one Polaris submarine at sea into the mid 1990s by operating HMS RESOLUTION and HMS REPULSE for two years beyond their intended decommissioning date.

Because of the dangers inherent in operating nuclear reactors on board submerged warships, safety considerations should be paramount. In the interest of safety, remedial action should have been carried out at one of the dockyards before any of the older submarines was used. Submarines should certainly not have been sent on long patrols before detailed inspections had been completed.

These dangerous practices are the result of an overriding operational requirement to keep one Polaris boat at sea at all times. There is no longer any strategic rationale to support this practice [1]. The lives of submariners and the safety of the general public are being put at risk to sustain a policy which is now irrelevant.



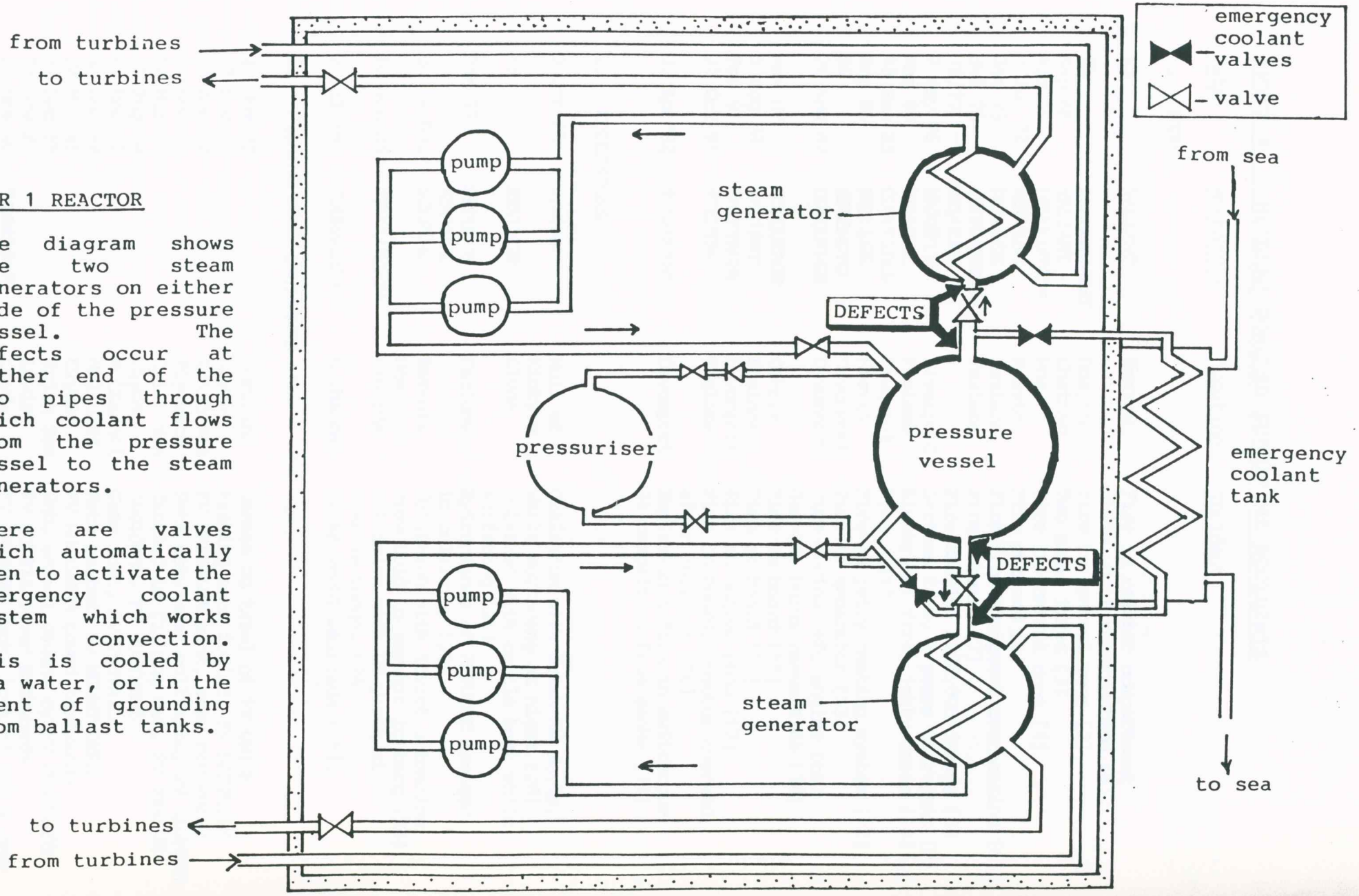
PWR 1 REACTOR

The diagram shows one side of the primary coolant circuit linking the pressure vessel and one of the two steam generators. Three pumps keep the coolant circuit flowing. To make the reactor critical, the circuit is brought up to high pressure by the pressuriser and the control rods are moved to the optimum height. In the steam generator, heat is extracted into the secondary steam circuit which drives the turbines.

PWR 1 REACTOR

The diagram shows the two steam generators on either side of the pressure vessel. The defects occur at either end of the two pipes through which coolant flows from the pressure vessel to the steam generators.

There are valves which automatically open to activate the emergency coolant system which works by convection. This is cooled by sea water, or in the event of grounding from ballast tanks.



ANNEX A NUCLEAR POWERED SUBMARINE ACCIDENTS

date	submarine	location	Incident
1. FIRES			
63	VALIANT	Barrow	Fire in reactor compartment while under construction [1]
65	DREADNOUGHT	Rosyth	Fire in control room [2]
Sep 68	VALIANT	Chatham	Two small fires [3]
Aug 70	RESOLUTION	Rosyth	Fire in control room [4]
3 Jul 72	REPULSE	Rosyth	Fire onboard [5]
Jan 75	REPULSE	Faslane	Fire from equipment overheating [6]
Jul 75	COURAGEOUS	Faslane	Fire onboard [7]
76/77	REPULSE		Fire causing £200,000 damage [8]
2 May 76	WARSPITE	Liverpool	Serious fire, 2 years to repair [9]
Mar 80	REVENGE	Faslane	Electrical fire, jetty cable [10]
18 Sep 83	CONQUEROR	Devonp/t	Fire [11]
Sep 85	REPULSE	Rosyth	Fire on jetty heating system [12]
86	SPLENDID	Devonport	Fire in generator [13]
26 Aug 87	CONQUEROR	Devonport	Fire during DED, engine room damage, burns casualties [14]
May 88	CONQUEROR	Gibr/r	Fire on board [15]
5 Aug 88	VALIANT	Faslane	Fire on board [16]
Feb 91	SWIFTSURE	Devonport	Fire in engine room [17]
20 Oct 91	SCEPTRE	Faslane	Fire on board; reactor checked after incident [18]
30 Apr 92	TURBULENT	Devonport	Explosion & Fire in switchroom 24 casualties from smoke [19].
2. COLLISIONS			
7 Oct 69	RENOWN	Mull of Kintyre	Collision with Irish MV Moyle, while surfacing at night [20]
69	REVENGE	Clyde	Collided with cattle boat while surfacing [21]
Jan 73	REPULSE REVENGE	Faslane	Hydroplanes of REPULSE damaged in collision [22]
early 80s	SCEPTRE	Barents Sea	Collision with Soviet submarine crew told to say hit iceberg [23]
10 Jun 85	RESOLUTION	Florida	Collision with US yacht at missile range. [24]
2 Jul 88	COURAGEOUS	N Channel	Sinks yacht Dalriada [25].
3. FISHING BOAT INCIDENTS 1980 - 1990 [26]			
4 Nov 80		Portland	Damage to trawl of FV UNION
17 Nov 81		Clyde	Fishing nets fouled, FV SAPPHIRE
18 Apr 82		Irish Sea	FV SHERALGA sunk, crew recovered
1 Dec 82		Plymouth	Nets cut, near collision, FV ALGERIE
10 Mar 83		Irish Sea	Tangled in fishing net, FV TARGUEN
11 Aug 84		Clyde	Incident, FV HUNTRESS
6 Dec 87		N Channel	Gear lost, FV PREVAIL
3 Dec 88		Malin Hd	Nets parted, FV MOUNT DEEN
26 Mar 89		Clyde	FV HUNTRESS towed backwards
12 Sep 89		Irish Sea	Sub. aerial caught by FV CONTESTER
13 Nov 89		Lewis	FV SCOTIA towed backwards
22 Nov 90	TRENCHANT	Clyde	FV ANTARES sunk, loss of all 4 crew

date	submarine	location	Incident
4. GROUNDINGS			
5 Nov 67	REPULSE	Barrow	Ran aground after launch [27]
17 Apr 71	RENOWN	Clyde	Hits sea bed in post-refit trials, Commander court-martialled [28]
13 Oct 89	Swiftsure class	Loch Linnhe	Submarine scraped the bottom [29]
5. BREAKDOWNS AT SEA			
Jan 68	RESOLUTION	Atlantc	Defect in electrical generator on way to Florida; returned to Faslane [30]
19 Oct 68	WARSPITE	N Atl	Ice damage to conning tower & superstructure [31]
19 Sep 74	SOVEREIGN	W Coast Scotland	Steering defect; later under tow [32]
78	REVENGE		Steam leak, disaster averted [33]
12 Aug 80	SOVEREIGN	Plym/th Sound	Towed to Devonport after break down on trials [34]

ANNEX B PROBLEMS WITH PWR 1

1. PWR PROBLEMS AT DOCKYARDS DURING REFITS AND DEDS

70	DREADN/T	Rosyth	Refit extended by 10 months, due to serious problems [1]
73	CONQUEROR	Chatham	2 major defects found at end of DED [2]
74/75	DREADN/T	Chatham	Refit extended due to extra work needed on reactor welds [3]
75/76	RESOLUTION	Rosyth	Reactor welders brought from Chatham & Devonport; Problems during final reactor power testing [4]
77/78	SOVEREIGN	Chatham	Not a refit but special repairs for over a year; SOVEREIGN later said to have major reactor problems [5]
79/83	SWIFTSURE	Devonpt	Refit lasted 4 years [6]
80	RENOWN	Rosyth	Major technical problem identified at end of refit; 150 workers sent to Faslane after refit completed. [7]
May 80	REVENGE	Rosyth	High radiation levels, large amount of waste produced in decontamination [8]
83/84	RESOLUTION	Rosyth	Brown stains found throughout reactor pipework; Problems with crucial weld on Main Seal Membrane; Main feed nozzles replaced on both Steam Generators; Workers at Rosyth had high radiation doses; 3 crews working in reactor on 3 jobs at once [9]
84	WARSPITE	Rosyth (DED)	Serious reactor problem needed "innovative engineering .... new ways to tackle old problems" [10]

date	submarine	location	Incident
84/6	REPULSE	Rosyth	"Major innovative repair" in reactor compartment; Cutting machine designed to remove stress corrosive cracking from Steam Generators [11]
85/86	?	Rosyth	Poor workmanship & standards affecting safety led to board of enquiry over refit; Problem had not been identified when it should have and corrective action was very difficult; possibly REPULSE [12]
86/8	VALIANT	Rosyth	"Showing her age"; A number of "novel tasks" carried out on the reactor; Special tool invented by RRA to tackle an awkward problem with the Steam Generator; "This situation has never occured before." - Babcock Thorn; This will add 6 months to refit. [13]
Mar 90	SCEPTRE	Devonport	Coolant leak in Primary Circuit [14]
Dec 89	WARSPITE	Devonpt	Defect discovered leading to decommissioning. [15]

2. OTHER PROBLEMS WITH PWR 1

1 Dec 80	DREADNOUGHT		Complete reactor shut down after serious machinery damage; reported as cracks in secondary cooling system [16]
15 May 81	VALIANT		Fault in main cooling system; hairline crack found on return to Devonport under own power; Plugged after reactor cooled down; "small quantity of water leaked out and drained into lead tank into a barge" [17]
82	CONQUEROR	Atlantc	Reactor shut down on route to Falklands [18]
Sep 91	TRAFALGAR	Coulport	Ventilation valves for reactor in wrong position on patrol; REVENGE diverted from Coulport where TRAFALGAR was berthed [19]

ANNEX C STATUS OF TEN OLDER SUBMARINES 1 MAY 1992

name	commissioned	location	status
VALIANT	1967	Rosyth	Probably decommissioned
WARSPITE	1968	Devonport	Decommissioned 1990
RESOLUTION	1968	Faslane	Used on operations
REPULSE	1968	Sea	Used on operations
RENOWN	1968	Rosyth	Five year refit
REVENGE	1969	Coulport	Decommissioned 1992
CHURCHILL	1971	Rosyth	Decommissioned 1990
CONQUEROR	1972	Devonport	Decommissioned 1990
COURAGEOUS	1972	Devonport	Decommissioned 1992
SWIFTSURE	1974	Rosyth	Possibly decommissioned

ANNEX D REFITS OF RESOLUTION CLASS

a. REFIT CYCLE FOR RESOLUTION CLASS AT ROSYTH 1970 - 1992

start date	recommission date	submarine
May 70	May 71	Resolution [1]
May 71	Jul 72	Repulse [2]
Nov 72	26 Jan 74	Renown [3]
Dec 73	19 Apr 75	Revenge [4]
Apr 75	Nov 76	Resolution [5]
Oct 76	7 Jul 78	Repulse [6]
Jul 78	3 May 80	Renown [7]
Apr 80	Jan 83	Revenge [8]
Aug 82	Sep 84	Resolution [9]
Sep 84	24 Oct 86	Repulse [10]
Nov 86	by May 87	Resolution DED [11]
Oct 87	?	Renown [12]

b. LENGTH OF SERVICE AT 1 MAY 92

	RESOLUTION	REPULSE	RENOWN	REVENGE
Commissioned	2 Oct 67	28 Sep 68	15 Nov 68	Dec 69
Age (a)	24 yr 8 mn	23 yr 8 mn	23 yr 6 mn	22 yr 5 mn
length of				
1st refit	1 yr	1 yr 2 mn	1 yr 2 mn	1 yr 4 mn
2nd refit	1 yr 7 mn	1 yr 9 mn	1 yr 10 mn	2 yr 6 mn
3rd refit	2 yr 1 mn	2 yr 1 mn	4 yr 7 mn	
total time in refits (b)	4 yr 8 mn	5 yr	7 yr 7 mn	3 yr 10 mn
in service: (a-b)	20 yr	18 yr 8 mn	15 yr 11 mn	18 yr 7 mn

ANNEX E DEPLOYMENT OF RESOLUTION CLASS 1990 / 1992

1. POLARIS SUBMARINES ON PATROL 1 JULY 1990 to 1 MAY 1992

submarine	from	to	patrol length	work up exercise	change over
REPULSE	?	23 Jul 90?	?	?	
REVENGE	Jul 90	28 Aug 90	?	?	?
RESOLUTION	16 Aug 90	3 Dec 90	109 days	16 days	12 days
REVENGE	2 Dec 90	18 Feb 91	79 days	3 days	12 hours
RESOLUTION	14 Feb 91	1 Jun 91	108 days	9 days	4 days
REVENGE	27 May 91	12 Jun 91	16 days	nil	4 days
RESOLUTION	7 Jun 91	8 Jul 91	31 days	nil	5 days
REVENGE	4 Jul 91	24 Sep 91	82 days	nil	4 days
REPULSE	20 Sep 91	23 Dec 91	94 days	23 days	4 days
RESOLUTION	18 Dec 91	14 Mar 92	89 days	nil	5 days
REVENGE	4 Mar 92	13 Apr 92	40 days	?	?
REPULSE	8 Apr 92			33 days	5 days

2. DEPLOYMENT OF INDIVIDUAL SUBMARINES

Table 1 above is based on the following information:

from	to	days	location	comment
a. HMS RESOLUTION				
	19 Jul 90	over 47	Faslane	
19 Jul 90	4 Aug 90	16	Sea	Work Up
4 Aug 90	16 Aug 90	13	Faslane	Visit to Coulport
16 Aug 90	3 Dec 90	109	Sea	Operational
3 Dec 90	25 Jan 91	53	Faslane	
25 Jan 91	3 Feb 91	9	Sea	Work Up
3 Feb 91	14 Feb 91	11	Faslane	Visit to Coulport
14 Feb 91	1 Jun 91	108	Sea	Operational
1 Jun 91	7 Jun 91	6	Faslane	Crew change
7 Jun 91	8 Jul 91	31	Sea	Operational
8 Jul 91	29 Nov 91	144	Faslane	RRA Sep
29 Nov 91	2 Dec 91	3	Coulport	
2 Dec 91	16 Dec 91	14	Faslane	
16 Dec 91	18 Dec 91	2	Loch Long	
18 Dec 91	14 Mar 92	89	Sea	Operational
14 Mar 92			Faslane	
b. HMS REPULSE				
	23 Jul 90	over 23	Sea	Operational
23 Jul 90	20 Aug 91	394	Faslane	Reactor work
20 Aug 91	12 Sep 91	23	Sea	Work up & L Goil
12 Sep 91	20 Sep 91	8	Coulport	
20 Sep 91	23 Dec 91	94	Sea	Operational
23 Dec 91	30 Dec 91	7	Coulport	
30 Dec 91	5 Mar 92	65	Faslane	RRA (Jan/Feb)
5 Mar 92	8 Apr 92	33	Sea/Coul	Trials
8 Apr 92			Sea	Operational
c. HMS REVENGE				
1 Jul 90	28 Aug 90	59	Sea	Work up & operational
28 Aug 90	15 Nov 90	79	Faslane	
15 Nov 90	18 Nov 90	3	Sea	Work up
18 Nov 90	2 Dec 90	14	Fas/Coul	
2 Dec 90	18 Feb 91	78	Sea	Operational
18 Feb 91	27 May 91	98	Faslane	
27 May 91	12 Jun 91	16	Sea	Operational
12 Jun 91	4 Jul 91	22	Faslane	
4 Jul 91	24 Sep 91	82	Sea	Operational
24 Sep 91	13 Feb 92	141	Faslane	
13 Feb 92	21 Feb 92	8	Sea	Trials
22 Feb 92	3 Mar 92	10	Fas/Coul	
4 Mar 92	13 Apr 92	40	Sea	Operational
13 Apr 92			Fas/Coul	

ANNEX F AVAILABILITY OF POLARIS SUBMARINES 1985 - 1997

The availability of Polaris submarines is indicated in the following table. This shows the number of years submarines have been in service since their last refit. The planned schedule shows what would have been expected with 2 year refits on HMS RENOWN and HMS REVENGE. The revised schedule is based on the current situation. The expected operational availability of Trident submarines is in brackets and is based on an service date for HMS VANGUARD of late 1994 or early 1995 [1]. Submarines spend 9 months on trials after refits and so year "one" is shown in brackets.

	PLANNED SCHEDULE					REVISED SCHEDULE			
	RESOL	REPUL	RENOW	REVEN		RESOL	REPUL	RENOW	REVEN
1985	(one)	refit	five	three	1985	(one)	refit	five	three
1986	two	refit	six	four	1986	two	refit	six	four
1987	three	(one)	seven	five	1987	three	(one)	seven	five
1988	four	two	refit	six	1988	four	two	refit	six
1989	five	three	refit	seven	1989	five	three	refit	seven
1990	six	four	(one)	refit	1990	six	four	refit	eight
1991	seven	five	two	refit	1991	seven	five	refit	nine
1992		six	three	(one)	1992	eight	six	refit	ten
1993		seven	four	two	1993	nine	seven	(one)	
1994			five	three	1994		eight	two	
1995	(VAN)		six	four	1995	(VAN)	nine	three	
1996	(VAN)	(VIC)		five	1996	(VAN)	(VIC)	four	
1997	(VAN)	(VIC)	(VIG)		1997	(VAN)	(VIC)	(VIG)	

ANNEX G ANONYMOUS INFORMATION GIVEN TO SCOTTISH CND

"There are cracks around the watery legs paint work in PC in SG in both the SSN boats and Polaris boats and they don't know how to fix it ... we are talking about Chernovyl ... its too dangerous to talk around here"

(January 1990)

"The fractures have been obvious for years and the reason for the withdrawal of the submarines is that the MoD is afraid that the Emergency Cooling System does not work at all. There was an indicident at Faslane about 2 years ago when there was a near melt down .... the Emergency Cooling System does not work."

(February 1990)

"As per my prior information re nuclear submarines which led to their withdrawal, further advise that reactor fractures while serious are secondary, the high hazard is final coolant failures; thus the prior incident could have resulted in catastrophe, certainly in Clyde Basin"

(October 1991)

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SECTION 1

1 2 US and 5 Soviet nuclear powered submarines have been lost at sea, NP3, p7; RN does not have the unimpeachable nuclear safety record claimed, HC 69 90/91 p10.
2 Guardian 3 May 76, Times 3 May 76
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4 Western Morning News 1, 2 May, Plymouth Evening Herald 30 Apr, 1 May
5 Not reported as a collision but fire damage. Hydroplanes taken from HMS RENOWN in Rosyth, HA 19 Jan 73, DP 2 Feb 73. Several reliable sources have confirmed this was a collision.
6 D Forghan, weapons officer, HMS SCEPTRE, this week, 19 Sep 91; JE Moore & R Compton Hall, Submarine Warfare, Michael Joseph, 1986, p39.
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8 NP3, p2
9 HA 23 Feb 79
10 Naval Nuclear Bases, p4
11 Submarine Warfare, p39.
12 HC 369 90/91, p86f
13 HC 316 88/89, p40f
14 HC 36 80/81,
15 Spotlight Feb 84
16 Spotlight Sep 79
17 HC369 90/91, p86f
18 This Week, 19 Sep 91
19 HC 399 72/73 px
20 HC 36 80/81 p201

SECTION 2

1 Independent 31 Jan 90, HC 69 90/91, p27
2 HC 369 90/91 p 64; RRA couldn't repair - Observer 11 Nov 90
3 Sightings from Faslane Peace Camp
4 HC 337 91/92 p3, DP Oct 87

5 Scotsman 28 Sep 91; this week, 19 Sep 91
6 HC 337 91/92 p3,5
7 HC 337 91/92 p38
8 HC 69 90/91, p30; HC 369 90/91 p 64
9 HC 69 90/91 p30
10 Sightings from Faslane Peace Camp
11 Navy News Dec 90; HC 69 90/91 p30
12 Sightings from Faslane Peace Camp
13 HC 337 91/92 p 37
14 HC 69 90/91 p 20
15 Reactor System Defects
16 R Farmer, This Week, 19 Sep 91; Independent 11 May 91; Reactor System Defects.
17 VSEL Link Jun 91
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20 Sunday Mail 22 Feb 88; DP 4 Mar 88
21 letter from submariner, Reactor System Defects, p6
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1 Daily Record, 22 Jan 90
2 Scotsman 31 Jan 903 HC 69 90/91, p19, 27
4 Times 29 Oct 91
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6 Spotlight Mar 83
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8 Statistical Bulletin radioactive discarges in Scotland, 1980-84, Scottish Office
9 HC 361 88/89 p41
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11 Spotlight Feb 84
12 Welding of handhole toroid on Steam Generator of HMS RESOLUTION, Spotlight Nov 83.
13 R Farmer, This Week, 19 Sep 91
14 Scotsman 28 Sep 91
15 5 containers from RRA were alongside HMS REPULSE at Faslane, late Jan & early Feb 92
16 Independent, 19 Nov 90
17 R Farmer, This Week, 19 Sep 91
18 HC 369 90/91, p53
19 Guardian 1 Oct 91

SECTION 4

1 Nov 90, HC 69 90/91, p19
2 Apr 91, HC 369 90/91, p12f
3 This Week, 19 Sep 91; HC 337 91/92 p xiv
4 J Crane, The Submarine, BBC, 1984, p180f
5 HC 369 90/91, p35
6 The submarine, p197; FW Lipscomb, The British Submarine, Conway Maritime Press, 1975, p 231
7 The submarine, p9
8 SIPRI yearbook 1986, p61

SECTION 5

1 DP 9 May 80, 2 Oct 87; New cores exceeded the previous limit of 6 years, HC 479 84/5, q1897
2 Nuclear Engineering International, Mar 88
3 HA 26 Nov 82; HC 337 91/92 p 3
4 Navy News Jan 92
5 Independent 11 May 91, Scotsman 28 Sep 91
6 Submarine Warfare, p39
7 HC 337 90/91 p4
8 HMS RENOWN will not be out of refit until late 1992, HC 337 90/91 pxiv

SECTION 6

1 Observer 14 Feb 88
2 Guardian 15 Feb 88

SECTION 7

1 There is no longer a need to be ready for a bolt from the blue attack according to Michael Clarke, Director, Centre for Defence Studies, Scotsman 7 May 1992.

ANNEX A

1 Sanity Sep 89, p5
2 NP3, p31
3 Sanity Sep 89, p5; NP3, p37
4 DP 21 Aug 70
5 DP 7 Jul 72
6 HA 10 Jan 75
7 HA 11 Jul 75
8 Navy News May 76; NP3, p54
9 Guardian 3 May 76; HA 7 May 76
10 HA 7 Mar 80
11 Sanity Sep 89, p5; NP3, p64
12 DP 20 Sep 85; Spotlight Apr 86
13 Western Morning News 1 May 92; Plymouth Dump Information Group
14 Guardian 28 Aug 87; NP3, p70
15 NP3, p71
16 Observed by Faslane Peace Camp
17 Western Morning News 1 May 92; Plymouth Dump Information Group
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20 HA 7 Oct 69; NP3, p38
21 Glasgow Herald 2 Feb 82
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24 NP3, p67
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28 Glasgow Herald 2 Feb 82
29 Sunday Mail 22 Oct 89
30 HA 12 Jan 68; NP3, p35
31 NP3, p37
32 NP3, p47
33 HA 23 Feb 79
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ANNEX B

1 NP3, p39
2 Spotlight Dec 73
3 HC362 80/81 p113
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6 Reactor System Defects, figure 5
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17 NP3, p59
18 HA 22 May 81
19 Sightings and information from Faslane Peace Camp

ANNEX D

1 HA 29 May 70, 28 May 71
2 DP 25 May 71; HA 5 Jan 73
3 DP 24 Nov 72, 25 Jan 74
4 DP 1 Feb 74, 18 Apr 75
5 DP 11 Apr 75; HA 27 Nov 76
6 Spotlight Dec 76; HA 21 Jul 78
7 DP 7 Jul 78, 9 May 80
8 DP 25 Apr 80; HA 26 Nov 82; HC 337 91/92 p3
9 DP 20 Aug 82
10 HA 2 Nov 84; Spotlight Nov 86
11 Spotlight Nov 86
12 DP 2 Oct 87

ANNEX E

based on sightings from Faslane Peace Camp

ANNEX F

1 HC 337 91/92 pv